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# HOW TO MEASURE FOREST FIRE DANGER IN THE SOUTHEAST



by

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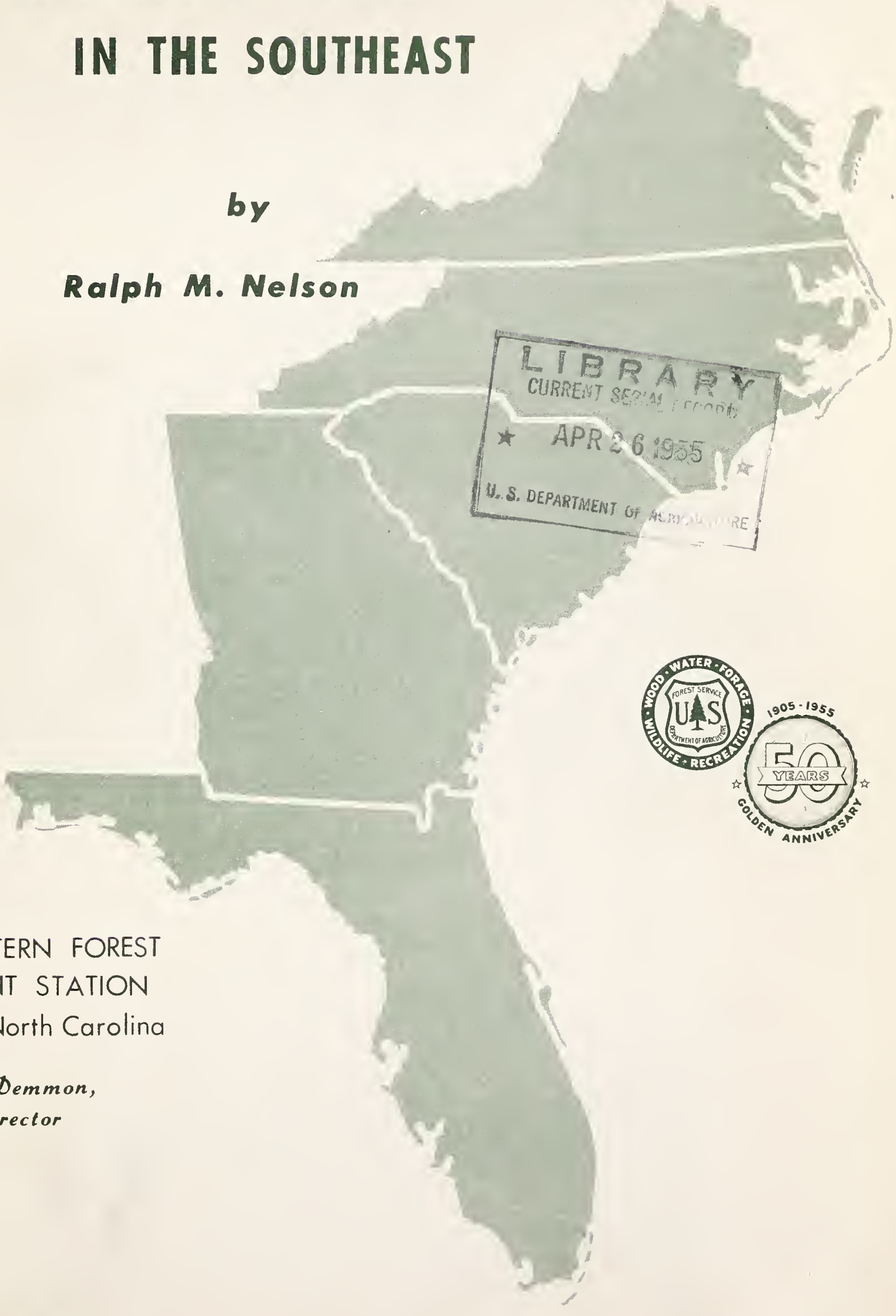



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Acknowledgment is made to Cooperator John J. Keetch, Forester (Fire Control) of Region 7. From the beginning he has contributed greatly to the development and application of fire danger measurement in the East. Type 8 meter is very largely his work. New material in this Station Paper is based mostly on his knowledge and experience.

# HOW TO MEASURE FOREST FIRE DANGER IN THE SOUTHEAST

by

Ralph M. Nelson, Division of Forest Fire Research
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## INTRODUCTION

Hundreds of fire danger stations are located in the Eastern and Southern United States. Records from these stations have been found in many ways to be very useful guides in the highly technical job of fire control. But if reliance is to be placed on the records, and the best use is to be made of danger measurements, they must be taken at properly located stations, instruments must be kept in good operating condition, and observers must be trained to take and record measurements accurately.

Much emphasis is placed on close adherence to standards of location and operation. If not observed, the relative weights given to the several variables on the meters will no longer apply and results will be erroneous.

The purpose of this paper is to summarize, in one convenient place, standards for locating, maintaining, and operating danger stations that have been established according to the system developed by the Southeastern Forest Experiment Station. Much of the information contained in the paper, and certain details of operation, here omitted, will be found in the following publications:

Jemison, George M., Lindenmuth, A. W., and Keetch, J. J.
1949. Forest fire-danger measurement in the Eastern United States. USDA Agriculture Handbook No. 1

Lindenmuth, A. W., Jr., and Keetch, J. J.
1949. Open method for measuring fire danger in hardwood forests. Southeastern Forest Expt. Sta. Tech. Note No. 71.

Keetch, John J.
1954. Instructions for using forest fire danger meter type 8. Southeastern Forest Expt. Sta., Station Paper No. 33.

This paper is written primarily for those who have the responsibility of supervising danger station operation, but it is hoped that it will also be of value to those who take and record danger measurements.

## WOODS VERSUS OPEN STATIONS

In planning new stations or in relocating old ones, the question usually arises whether to establish an open or woods type. If instructions are followed, both will give comparable records. The open station has a number of advantages in that woods sites change, whereas the same degree of shading and wind exposure can be readily maintained at open stations. This greater uniformity is an advantage particularly where comparisons among stations are wanted or where records are grouped to obtain an over-all picture of the fire danger situation. There is more certainty that differences are real rather than the result of non-conformance with standards.

Sometimes, in order to obtain the services of a careful and conscientious observer, it is desirable, or even necessary, to move the station to the observer rather than the reverse. In such instances a satisfactory woods site may be difficult or impossible to find. It is thus a distinct administrative advantage to have the choice of two types of exposure in selecting locations.

In addition to the fact that open sites which meet location standards are more easily found, they are often more readily accessible. Facilitating the ease of danger measurement can mean the difference between good and only fair records.

For the reasons mentioned, our preference is for open stations wherever possible.

## HOW MANY STATIONS?

There can be no specific answer to the question, "How many danger stations should I operate?". Differences in topography, weather, fire occurrence, size of administrative divisions, and patterns of land use are the major variables that have to be evaluated before a sound decision can be reached. Basic to such evaluation are maps of administrative units differentiated into zones of weather, fire occurrence, and danger measurements from well located and operated stations. Administrative policy is sometimes a governing consideration. Some believe that placing a station in each administrative subunit or political subdivision has merit; others are content with a more widely dispersed network of stations.

In USDA Handbook No. 1, one station was suggested for 150,000 acres in the mountains and one per 300,000 acres in rolling or flat country. This is a good general standard where a very high level of protection is required. Where finances will only permit a less intensive degree of protection, doubling or trebling the acreage per station will still provide a fair network if it is properly operated.

As a comparative measure of spacing, stations equally spaced at 10, 20, 30, or 40 miles apart will each have a circular coverage of roughly 50,000, 200,000, 450,000, and 800,000 acres respectively.

Where stations are widely spaced, it is doubly important that they be located according to standards. As reliable records accumulate, it becomes possible to make a sound comparison of one station with another and to determine where additional stations should be established to fill holes in the network.

Certain key stations should be operated throughout the year, the number depending on size and variability of the area to be covered. Men in charge of districts will thus avoid being caught unprepared in off-season fire periods.

Because rainfall is the most important single variable entering into reduction of fire danger, the value of a station can be considerably increased by supplementing it with rain gages located at strategic points in the measurement area. This is especially true during fire seasons and where stations are widely separated, and during periods when local showers are common.

## HOW TO SELECT SITES FOR STATIONS AND HOW TO INSTALL EQUIPMENT

Regardless of whether an open or woods site is selected, certain standards must be met. This is necessary because the most accurate of observers or the best of meters will most certainly not counterbalance the faults of a poorly located station.

Three major items need to be considered: exposure of fuel moisture sticks, location of the anemometer, and placement of the rain gage. A fourth item, accessibility, may be equally important, but it is one for which specifications cannot be written.

Each of the three divisions in the Southeast, upper coastal plain, piedmont, and mountains, presents different problems in station location. For that reason each division will be treated separately.

It is assumed that in the coastal plain and piedmont most stations will be located at tower sites, principally because towermen can conveniently take danger measurements during the course of their regular jobs. Our specifications are therefore slanted in that direction.

## UPPER COASTAL PLAIN

### Open Stations

Fuel moisture sticks.--A site must be selected which is not shaded at any time during the day by obstructions such as trees, buildings, or towers. Artificial shade must be provided for the sticks in order to approximate forest leaf cover. Also, there must be different degrees of shade to simulate conditions when trees are leafless and when they are in full leaf. This is accomplished by exposing sticks under one or six layers of 14- or 16-mesh screen. In the spring when leaves on the hardwood trees

are half grown, the change is made from one layer to six layers. In the fall when half the hardwood leaves have fallen, the change is made from six layers to one layer.

Screens made of 14- or 16-mesh copper or bronze, 36 inches square, and mounted in a rigid frame, are recommended. The sticks should be supported on wire wickets 8 inches above a layer of leaf litter 4 inches thick, and 4 inches below the screen.

Specifications for assembling a sturdy frame of metal will be found on page 9 of Technical Note No. 71. Less permanent but entirely usable assemblies can be made of wood treated with pentachlorophenol or other preservative.

Screens should be kept free of leaves or other debris, and they should be restretched or replaced when they become sagged or damaged. Grass or weeds should be clipped periodically for a distance of approximately 6 feet surrounding fuel beds. The litter can be kept in place by a square frame of 2 x 4's or similar material, across which is tacked a piece of poultry wire. This will insure an even litter bed of the required depth.

In general, sticks should be placed south of the weighing shelter, and should be free of shadows cast by fence posts, stumps, or other objects.

Anemometers.--Lookout towers are convenient structures on which to mount anemometers. There is no difficulty in obtaining the proper elevation for instruments and they are easily serviced. Also, a wire can be strung from the anemometer to the cab, which will permit a reading of wind velocity any time the observer chooses. The anemometer should be securely attached to the guard rail or other convenient member midway between the first and second landings below the cab, provided this elevation clears the tree canopy by 50 feet or more. If not, the anemometer will have to be mounted at least 10 feet above the cab. Wind speeds at such elevations approach those at airport exposures and it, therefore, becomes necessary to convert tower velocities to open station velocities according to table 1. The table has not been thoroughly tested, but it is the best we can present with our present knowledge.

If the anemometer cannot be exposed according to the above standards, it then becomes necessary to erect an anemometer according to the following specifications.

In selecting an open site, try to find one having a radius of not more than 10 times the height of surrounding trees or buildings. Also try to achieve wind balance. For example, if trees on one side of the field are 60 feet tall and on the opposite side 20 feet, the station should not be equidistant from the two stands but closer to the shorter stand.

The basic height for anemometers at open stations is 20 feet. To this figure must be added the average height of brush or other ground cover, and a correction for the wind obstruction created by buildings or forest stands. This correction can be figured from table 2. Example: Assume the height of an adjacent stand to be 30 feet and that a convenient

site for the anemometer is 90 feet distant. Read down in the column headed 30 until opposite the figure 90 in the extreme left hand margin. The proper height of the anemometer is read as 30 feet, in addition to whatever allowance is added for height of ground cover. The procedure can be reversed to determine the distance an anemometer should be erected away from an obstruction, given a certain anemometer height. A description of a suitable anemometer mounting and mast is given on page 6 of Technical Note No. 71. However, we do not recommend such a mast mounting for heights above 25 feet. Higher mountings require a tower or pole, which should, of course, permit servicing the instrument.

Table 1.--Conversion of wind velocity measured at fire towers to the open station standard wind velocity (table compiled by J. J. Keetch)

(In miles per hour)

| Tower velocity | Open station velocity | Tower velocity | Open station velocity | Tower velocity | Open station velocity |
|---|---|---|---|---|---|
| 0-1 | 0 | 27-28 | 11 | 52-53 | 21 |
| 2-3 | 1 | 29-31 | 12 | 54-56 | 22 |
| 4-6 | 2 | 32-33 | 13 | 57-58 | 23 |
| 7-8 | 3 | 34-36 | 14 | 59-61 | 24 |
| 9-11 | 4 | 37-38 | 15 | 62-63 | 25 |
| 12-13 | 5 | 39-41 | 16 | 64-66 | 26 |
| 14-16 | 6 | 42-43 | 17 | 67-68 | 27 |
| 17-18 | 7 | 44-46 | 18 | 69-71 | 28 |
| 19-21 | 8 | 47-48 | 19 | 72-73 | 29 |
| 22-23 | 9 | 49-51 | 20 | 74-76 | 30 |
| 24-26 | 10 | | | | |

Caution must be used in establishing stations at lookout towers. If it is possible to see over the top of the anemometer cups in a level line in all directions without meeting an obstruction, the site is too exposed and will give too high wind velocities. This difficulty, of course, does not occur where the anemometer is mounted near the top of a tower and where wind speeds are converted according to table 1.

Rain gages.--These should be firmly mounted, the tops should be level, and they should be placed far enough away from obstructions to collect the free fall of precipitation. A $45^{\circ}$ angle from the top of the gage should clear the nearest obstruction, which will place it at a distance at least equal to the height of the obstruction. Specifications for a suitable gage mount will be found on page 28 in USDA Handbook No. 1.

Table 2.--Computations for anemometer height according to height of obstruction and distance to obstruction (table compiled by J. J. Keetch)

(In feet)

| Distance to obstruction (Feet) | Height of obstruction | | | | | | |
|---|---|---|---|---|---|---|---|
| | 10 ft. | 20 ft. | 30 ft. | 40 ft. | 50 ft. | 60 ft. | 70 ft. |
| 10 | 27 | 37 | 47 | 57 | 67 | 77 | -- |
| 20 | 25 | 34 | 44 | 53 | 63 | 74 | -- |
| 30 | 23 | 32 | 41 | 50 | 60 | 70 | -- |
| 40 | 22 | 30 | 39 | 48 | 58 | 67 | 77 |
| 50 | 21 | 28 | 37 | 46 | 55 | 65 | 74 |
| 60 | 20 | 27 | 35 | 44 | 53 | 62 | 72 |
| 70 | -- | 25 | 33 | 42 | 51 | 60 | 69 |
| 80 | -- | 24 | 32 | 40 | 49 | 58 | 67 |
| 90 | -- | 23 | 30 | 38 | 47 | 55 | 64 |
| 100 | -- | 22 | 29 | 36 | 45 | 53 | 62 |
| 120 | -- | 21 | 26 | 33 | 42 | 50 | 59 |
| 140 | -- | 20 | 24 | 31 | 39 | 46 | 55 |
| 160 | -- | -- | 22 | 28 | 36 | 43 | 51 |
| 180 | -- | -- | 21 | 26 | 33 | 40 | 48 |
| 200 | -- | -- | 20 | 24 | 30 | 37 | 45 |
| 220 | -- | -- | -- | 23 | 28 | 34 | 42 |
| 240 | -- | -- | -- | 22 | 26 | 32 | 39 |
| 260 | -- | -- | -- | 21 | 25 | 30 | 37 |
| 280 | -- | -- | -- | 20 | 23 | 28 | 34 |
| 300 | -- | -- | -- | -- | 22 | 26 | 32 |
| 350 | -- | -- | -- | -- | 20 | 23 | 27 |
| 400 | -- | -- | -- | -- | -- | 21 | 24 |
| 450 | -- | -- | -- | -- | -- | 20 | 21 |
| 500 | -- | -- | -- | -- | -- | -- | 20 |

### Woods Stations

We do not recommend woods stations for pure pine types even in fairly open stands. This is because fuel moisture sticks will receive too much shade in the spring and fall and too little shade in the summer. Also, pine stands change quickly because of rapid growth, and it is, therefore, difficult to maintain the same degree of exposure. However, if a woods station is desired in the upper coastal plain and a suitable hardwood site is available, it should be located according to specifications for a mountain woods station.

## PIEDMONT

### Open Stations

Fuel moisture sticks.--Use the same specifications described for open stations in the upper coastal plain.

Anemometers.--As in the upper coastal plain, most danger stations will probably be at lookout tower sites. Because these are invariably on elevated ground, anemometers should not be mounted near the top of the tower as was recommended in the coastal plain. If the tower site is wooded, our best suggestion is to select a point on the tower where the line of sight clears the top of the forest canopy and to place the anemometer 30 feet above this point. If the site is bare or has only shrubby vegetation, place the anemometer 20 feet above the average height of the grass or low vegetation cover. In both situations, wind converting factors in table 1 must be used.

If the tower site is relatively flat and receives an average amount of wind, the specifications on pages 4-5 should be used.

Rain gages.--The same specifications apply as for any rain gage--a location which assures a catch of rain uninfluenced by any obstruction.

### Woods Stations

Use the same specifications as for mountainous areas.

## MOUNTAINS

### Open Stations

Many difficulties can be avoided if sites for open stations are selected in broad valleys or flat country. Exposed peaks, knolls, gaps, narrow valleys, and sheltered spots should be avoided. Neither should sites be chosen which are near enough to lakes or streams so that fuel moisture sticks would be affected. The open site should not be too large. Airports, for example, are too open.

Fuel moisture sticks.--Specifications for exposing sticks under screens in the mountains are the same as for the coastal plain. However, the decision to change from one set of screens to 6 sets, and the reverse, is not always easy to make. Whether to estimate foliage density on the basis of conditions in the valleys or at different elevations on slopes in mountainous regions can best be decided by the district managers. The main consideration should be the elevation at which fire occurrence is greatest.

Anemometers.--Tower sites in mountainous areas are almost always too exposed to be suitable for anemometer locations and are, therefore, not recommended. However, clearings of satisfactory size can often be found at lower elevations. At such places, anemometers should be located according to calculations from table 2.

Rain gages.--See page 5.

## Woods Stations

A general principle in selecting a site for a woods station is that it should be as typical as possible of the general area to be sampled in regard to cover, topography, slope, and aspect. This, however, is too idealized a concept to be of much use in practical application, so the following guides are offered.

Fuel moisture sticks.--In the mountain and piedmont regions, choose a 10- to 20-percent slope if possible; level ground to 10-percent slopes, and 20- to 30-percent slopes are next best. Regarding aspect, a south to southwest exposure is preferable; west is next best; southeast and northwest slopes will do but are not recommended; east, northeast, and north aspects should be avoided. Choose a hardwood site, even in a pine-hardwood mixture where pine constitutes a good part of the stand. Age of stand is not important but the timber should be pole-sized or larger.

Fuel sticks should be exposed on wire supports 8 inches above the litter with the numbered side down. During the leafless season they should be so placed that they will be fully exposed to the sun, except for twig shade, and completely shaded when the overstory is in full leaf.

Anemometers.--These should be supported so that the cups are at or near the 8-foot level, assuming that the shrubby vegetation is sparse. If it is dense, a distance equivalent to the height of the vegetation should be added. No artificial barriers, such as buildings, should modify typical forest conditions in any direction. A rule of thumb is that the anemometer should not be nearer than 10 feet to trees 10 inches or larger in diameter.

If the ground is fairly level, the anemometer can be secured to the top of the weighing shelter. If the ground is sloping, the exposure will not permit equally free wind movement from all directions. Under such circumstances it may be necessary to move several hundred feet up slope to a wooded ridge and to string a wire from the anemometer to the weighing shelter or the observer's dwelling.

Rain gages.--As stated previously, the gage must be so located that a 45° angle from its top clears the nearest obstruction. If a sufficient opening in the woods is not available, one must be made or another site selected. At some woods stations the gage may have to be at one place, the sticks at another, and the anemometer at still another. This illustrates one of the occasional disadvantages of woods stations.

## GENERAL RECOMMENDATIONS

Suggested ground plans for a woods station will be found on page 22 of USDA Handbook No. 1, and for an open station on page 8 of Technical Note No. 71. For both types of installations we recommend a fenced enclosure to reduce the possibility of stick breakage by animals and molestation from passers-by.

Details about the construction of weighing shelters, mounting fuel moisture scales, and the buzzer arrangement for anemometers are not included in this paper. These subjects are discussed on pages 24-26 of USDA Handbook No. 1. We emphasize the desirability of having a glass window in the door of the weighing shelter. Otherwise, weighing sticks when there is wind can be very troublesome.

It goes without saying that danger stations should be maintained in a shipshape manner at all times. A well-kept enclosure, with neatly painted posts, signs, instrument shelters, and supports, draws immediate and favorable attention.

Do not combine open- with woods-station specifications--for example, an open station anemometer with a woods station stick exposure, or an open-type meter with a woods station. This has been done at a few places with completely unsatisfactory results.

## HOW TO MAKE MEASUREMENTS

The following instructions are taken directly from USDA Handbook No. 1.

### GENERAL

Accuracy of all readings is essential. Never guess at a value. Write reading down as soon as taken.

### FUEL MOISTURE

1. Instructions for new sticks: (a) the date when new sticks are first exposed and each date when a weathering correction is to be made should be recorded on the weathering correction card as soon as the sticks are placed out in the weather; (b) new sticks can be used 6 to 8 months; (c) destroy old sticks when new ones are put in use.

2. Scale should read exactly 0 percent when the 100-gram test weight is on the hook and the counterbalance slide is set at 100.0 grams. Check this weekly. If not reading 0, correct by loosening wing nuts and tilting scale up or down.

3. Before weighing sticks, be sure that the counterbalance slide on the horizontal beam is set correctly at the point indicated on the weathering correction card.

4. Weigh all 3 sticks together. Do not read the scale until the pointer has become still. Always tap the pivot block with finger or pencil just before reading, to avoid possible error from friction in the pivot.

5. Handle wood sticks with care--never with sweaty, dirty, or greasy hands--avoid splitting, chipping, or marring--brush off lightly with a clean, dry cloth any dirt that gets on sticks.

6. After weighing, always replace sticks on their supports with the numbered side down. Maintain adequate litter under sticks at all times.

7. If fuel moisture scale becomes sluggish, place a few drops of kerosene oil on the pivot--never use machine oil.

## WIND

1. To measure wind: (a) close switch; (b) listen for first signal; (c) immediately at the end of the first signal, start timing for a 2-minute period; (d) count all signals that occur for exactly 2 minutes, or 4 minutes if wind is gusty or variable; (e) refer to wind correction chart to determine true wind velocity. If no signals occur, the wind velocity is 0.

2. Oil anemometer once a month--use only 2 or 3 drops of a very light oil, such as typewriter oil or 3-in-1.

## RAIN

1. Rain is measured as follows: (a) remove funnel top of rain gage; (b) lower rain measuring stick down inside measuring tube until the stick rests on the bottom; (c) raise rain stick and read the top edge of the water line (the rain stick is marked off in hundredths of an inch and should be read to the nearest hundredth); (d) overflow that collects in the large can should be poured into the measuring tube, measured, and added together to get the total rainfall.

2. If snow is expected, remove funnel top and measuring tube, and let snow collect in large container. To measure, melt the snow, pour water into measuring tube and proceed as in measuring rain.

3. Always remove inner tube when there is danger of freezing weather.

## COMMON ERRORS IN MAKING MEASUREMENTS

Much can be learned about station location and operation from a review of danger records. This is particularly true if reports from neighboring installations are available for comparison. Differences between stations are, of course, to be expected, but if they are consistently large and seemingly unreasonable for a particular station during periods of settled weather, something is undoubtedly wrong. For example, records have been examined in which zero wind velocity was recorded for days on end. Similarly, fuel moistures of not more than 1 percent, and usually zero percent, have been reported for an entire month.

## FUEL MOISTURE

If danger station records appear consistently and unreasonably high or low, the following points should be checked:

(1) Are the sticks exposed according to standards of sun and shade?

(2) Does the observer have a weathering correction card and, if so, does he use it?

(3) Is the scale so mounted that the pointer stands at 0 when the slider is set at 100 and the 100-gram weight is suspended from the hook? Is the shelter wobbly or tilted so that it is difficult to level the scales?

(4) Does the observer know how to set the slider according to the weathering correction card? In one instance an observer set the slider at 105.0 when it should have been set at 100.5 according to the card.

(5) Does the pointer move freely and without touching the scale, and does the observer tap the pivot block before taking a reading?

(6) Are the screens kept free of debris and is the number of screens changed according to the stage of tree foliage?

(7) Are the sticks properly supported above a bed of leaf litter and at the right height?

(8) Does the hook on the scale fit loosely? Sometimes improvised hooks have been found which bind and make the scale inaccurate.

(9) Do the sticks swing free of the shelter when weighed?

Other points about fuel moisture sticks and weighing shelters are discussed on pages 36 and 37 of USDA Handbook No. 1.

## WIND VELOCITY

If wind speeds as entered on danger station records appear unusual, look for the following sources of error:

(1) Is the anemometer located at the proper height and at the proper distance from obstructions?

(2) Do the cups turn freely and evenly? This can be determined by removing the cup assembly and rotating the spindle gently with the finger. Is the anemometer oiled every month or two with one or two drops of light machine oil? Some anemometers were found that apparently had not been oiled since installation. Others had been oiled excessively and had become gummy and sluggish.

(3) Is the anemometer plumb and securely mounted?

(4) Is the inspection plate gasket weatherproof? Some have been found so leaky that the interior parts had become rusted.

(5) Are the anemometer cups undamaged, tightly attached to the arms, and faced in the right direction, that is, the open faces moving in a clock-wise direction? Several anemometers have been found where one cup had been reversed.

(6) Does the observer use the correct timing procedure? That is, does he begin counting signals immediately at the end of the first signal, and continue for exactly two minutes? When the wind is gusty or variable, does he take the average of two separate observations or, better, does he take a 4-minute reading?

(7) Does the observer have a wind correction chart for his specific type and model anemometer? Does he use it? Many records have been examined in which wind speed in even miles only had been recorded. Either the observer failed to use the correction chart or half miles of wind had been ignored. Correction charts for the several types of anemometers are on pages 51-58 of USDA Handbook No. 1.

(8) Are the wire connections to the anemometer and buzzer clean and tight? Occasionally loose connections are found in the anemometer, which will then sound fewer buzzes than it should. In multiple contact anemometers, such as the Friez Airways type, make sure that all contacts are working properly.

(9) Are the batteries and knife switch in good order?

(10) Is the anemometer carefully taken apart and cleaned once a year by a competent workman according to specific instructions provided by the manufacturer or those on pages 47-50 in USDA Handbook No. 1?

Additional instructions regarding anemometers appear on pages 39 and 40 in USDA Handbook No. 1.

## WHEN TO MAKE MEASUREMENTS

It is desirable to standardize, so far as possible, the time when measurements should be taken by all agencies within a given time zone. The hours of 9:00 a.m., and 2:00 and 5:00 p.m. appear to be generally acceptable. A considerable proportion of fires start between noon and 3:30 p.m. (at least in the North Atlantic States). Maximum temperatures and minimum relative humidities are also generally reached during this period. The 2:00 p.m. reading is, therefore, probably a good compromise for the basic observation. During dangerous periods, interim observations may also be desirable.

Whether to take morning and late afternoon readings depends upon administrative needs. During the fire season, a morning observation may be useful in indicating the weather patterns to be expected later in the day and in determining, for example, whether a lookout should be on his tower or whether he can be assigned other duties.

Five o'clock readings are recommended during the fire season because high danger occasionally continues into the evening.

At times it may be difficult or undesirable to arrange an observer's schedule so as to obtain readings at 2:00 o'clock. Under such circumstances, 1:00 o'clock readings are acceptable.

Observations at key stations should be made at 2:00 o'clock (or at 1:00 o'clock as explained) throughout the year.

## OPERATION OF THE METERS

The following instructions apply to the type 8 meter, W or O, and its variant 8-100, W or O. Type 8 is standard for all fire control agencies in Forest Service Region 7, and 8-100 has been proposed by States and the National Forest organization for the mountain and piedmont areas in Region 8.

The difference between the 8 and 8-100 meters is that the top of the Burning Index on the 8 is at 200, whereas the top of the 8-100 is at 100. This means that if identical values are set up on the two types, the 8-100 will give approximately one-half the Burning Index of type 8. This difference must be kept in mind by neighboring units using different meters. The Build-up Index is computed in exactly the same manner for both types of meters.

Type 8 is a more sensitive meter than type 5. For example, errors in fuel moisture measurements will cumulate on the Build-up Index and will, therefore, have a double effect on the daily measured danger.

Following is a discussion of the variables that are integrated on the 8 and 8-100 meters and the recommended tolerances in reading and recording measurements.

## CONDITION OF LESSER VEGETATION

Lesser vegetation means grasses, weeds, and shrubs as distinguished from tree foliage. Some observers have failed to recognize this distinction in the use of the meter. Condition of lesser vegetation is a variable on the danger meter; condition of tree foliage determines whether one or six layers of screens are to be used.

Condition 1 should be set up on the meter when the lesser vegetation is 90 percent or more cured, and condition 5 when the lesser vegetation is 90 percent or more green. Conditions 2, 3, and 4 are used during the transition stage, when the lesser vegetation is neither fully cured nor green. These intermediate stages cannot be defined with precision, so they must be determined on the basis of judgment. We recommend that the decision to change from one stage to another be made by an administrative officer and not left to the individual observer. Otherwise, any comparison or grouping of data may be meaningless.

During a "normal" season, the lesser vegetation marches progressively from stage 1 through to 5 and back to 1 with fair regularity. However, watch out for the effects of unusual weather.

In the spring, a series of unseasonably warm days will stimulate growth and may advance the season so rapidly that conditions 2, 3, and 4 may last only for short periods of less than a week each. Conversely, a late spring freeze may set the vegetation back a stage.

In the summer, periods of drought will, in effect, begin the curing of lesser vegetation even though this may not be particularly noticeable. During such conditions, the Build-up Index may be a useful guide. In the Appalachians and regions to the north and east 1/ consideration is given to shifting from condition 5 to 4 when the Build-up Index reaches 40, to condition 3 at 75, and condition 2 at 100. This is done arbitrarily at some stations with good results. Soaking rains may rather quickly revive vegetation back to the green stage.

In the fall, with normal distribution of rainfall, the vegetation condition will usually remain in condition 5 until the first killing frost. If 50 percent of the vegetation is immediately killed, the shift would be made to condition 3, by-passing condition 4. A succession of hard freezes might produce condition 2 in a few days.

## BUILD-UP INDEX

Fuel moisture sticks indicate the moisture condition of the surface layer of litter. In contrast, the Build-up Index reflects the cumulative drying of litter below the surface layer. Fires may start and burn readily when the upper fuels are dry, even if lower fuels are not readily ignitible. But if both layers are dry, fires will burn in general with greater intensity and spread faster.

The Build-up Index on the type 8 meter is designed to take into account this progressive drying of deeper fuels. It is a better measure than the factors, "days since rain" and "amount of rain" on type 5 meters,

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1/ We do not have sufficient information to suggest critical points for the piedmont region.

particularly during extended rainless periods, and during periods of recurring light rains. To some extent it is a rough measure of resistance to control in that when the maximum point of 100 is reached, fires in the deeper layers of litter are extinguished with great difficulty. Normal fire lines may not hold because fires can creep underneath in buried wood and rekindle fuel on the other side of the line. There are instances where men have had to return many times to a fire thought to be completely out.

The Build-up Index is easily computed. The central tab of the type 8 meter has a table which gives numerical build-up factors for different fuel moistures. One day's factor is merely added to the previous day's total during rainless periods; the sum of the factors is called the Build-up Index. When rains occur, the Build-up Index is reduced one point for every one-hundredth inch but never below 0. RULE--ALWAYS SUBTRACT TODAY'S RAIN BEFORE ADDING TODAY'S FACTOR. The following table will clarify this explanation.

Table 3.--Sample data for a 2 p.m. reading

| Day | Rain | Fuel Moisture | Build-up Factor | Build-up Index |
|---|---|---|---|---|
| | Hundredths of an inch | Percent | | 1/ (36) |
| 1 | 10 | 9.3 | 3 | 29 |
| 2 | 19 | 6.0 | 5 | 15 |
| 3 | 0 | 4.0 | 8 | 23 |
| 4 | 0 | 5.0 | 6 | 29 |
| 5 | 28 | 11.8 | 2 | 3 |
| 6 | 0 | 8.0 | 3 | 6 |
| 7 | 0 | 4.0 | 8 | 14 |

1/ A Build-up Index of 36 carried over from previous month.

## FUEL MOISTURE

Measurements should be recorded and set up on the meter to the nearest 1/10 percent up to 20 percent and to the nearest 1/2 percent above 20 percent. Although reading to the nearest 1/2 percent is close enough for practical purposes, we have found through experience that fewer errors are likely to occur if readings are made to the nearest 1/10 percent. There is no need to read sticks when snow is on the ground. However, in such instances the letter "S" should be entered in the record.

## WIND VELOCITY

Measurements should be recorded and set up on the meter to the nearest 1/2 mile according to the wind correction table which should be posted in the weighing shelter. On the "O" meter, never set wind speed at less than 3 miles per hour.

## RAINFALL

Use the 24-hour rain from 2:00 p.m. to 2:00 p.m. If there are auxiliary rain gages, take an average of the measurements. For record purposes use whole units. For example, record one-hundredth of an inch (.01) as 1, and 2 and 30 hundredths (2.30) as 230. This will avoid misplaced decimals. Ignore rains of less than one-hundredth inch.

There can be an exception to the use of the 2:00 p.m. rainfall. If a 9:00 a.m. reading today is wanted and rain has occurred since 2:00 p.m. yesterday, then this morning's record of rainfall may be used to reduce the 9:00 a.m. Build-up Index.

## HOW TO SET UP THE METER

Instructions for manipulating are printed on the backs of the meters, but for possible convenience they are also recorded here.

(1) Turn the CONDITION OF LESSER VEGETATION disc until the arrow on the central tab of the meter is exactly opposite condition 1, 2, 3, 4, or 5. Do not estimate a setting between the five positions.

(2) Turn the BUILD-UP INDEX disc until the computed Build-up Index is opposite the arrow at the outer edge of the CONDITION OF LESSER VEGETATION disc. Estimate position for amounts not shown between 25 and 100. Do not set at a higher reading than 100.

(3) Turn the FUEL MOISTURE disc until the exact percent of fuel moisture as measured is opposite the arrow at the outer edge of the BUILD-UP INDEX disc. Do not set a lower reading than the minimum fuel moisture printed on the meter.

(4) Turn the WIND VELOCITY disc until the measured velocity is exactly opposite the arrow at the outer edge of the FUEL MOISTURE disc. In using the "O" meter, if the wind velocity is less than 3 miles per hour, set at 3.

(5) Read the number representing the BURNING INDEX in the segment opposite the arrow at the outer edge of the WIND VELOCITY disc. Do not estimate fractional parts of segments.

## HOW TO KEEP RECORDS

The following is a sample Fire Danger Daily Record form which has been found generally satisfactory. A hypothetical 10-day record has been entered for illustrative purposes.

Assume that a new observer has been properly trained in taking measurements and in operating the meter, and is now to be instructed in the mysteries of record keeping. The following sequence will be helpful in explaining the method used.

Table 3 should be reviewed so that the observer knows how to find the proper build-up factor, how to subtract rain, and how to derive a Build-up Index. Beginning at the 9:00 o'clock reading on the 3rd of the month, for purposes of this illustration, he sees that the morning reading of "Condition of Lesser Vegetation" (Col. 2), "Fuel Moisture Percent" (Col. 3), and "Wind Velocity" (Col. 4), have been entered as 1, 50+, and 8.0, respectively. He then needs only to know the Build-up Index at 2:00 p.m. on the previous day, which was 29 (Col. 9), in order to set up the meter and derive the morning Burning Index, which was 1 (Col. 5). Proceeding along the same line to the 2:00 p.m. observation, he sees that the rainfall record at his station was 13 hundredths of an inch (Col. 6), that the amount at a secondary rain gage was 25 hundredths (Col. 7), and that the average of the two gages was 19 (Col. 8). Skipping columns 9 and 10 for the moment, he finds that the 2:00 p.m. fuel moisture percent was 6 (Col. 11) and

FIRE DANGER DAILY RECORD — April (month) 1954

Sample (State or Forest) — Sample (District) — Sample (Open) (Station) — John Doe (Observer)

| | | 9 A.M. EST | | | 24 HOUR RAINFALL 2 P.M. TO 2 P.M. (Hundredths) | | | 2 P.M. EST | | | | | 5 P.M. EST | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day of the Month | Condition of the Lesser Vegetation | Fuel Moisture Percent | Wind Velocity Miles per Hour | Burning Index | Amount of Rain Danger Station | Amount of Rain Coop. Station | Average Amount of Rainfall | Build-up Index | Build-up Factor | Fuel Moisture Percent | Wind Velocity Miles per Hour | Burning Index | Fuel Moisture Percent | Wind Velocity Miles per Hour | Burning Index | Highest Burning Index for the Day |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 1 | - - | - - | - - - | - - | - - - | - - - | - - 8- | 100-0 | Meter | - - - | - - - | - - - | - - - | - - - | - - - | - - |
| 2 | | | | | | | | 29 | | | | | | | | |
| 3 | 1 | 50+ | 8.0 | 1 | 13 | 25 | 19 | 15 | 5 | 6.0 | 6.5 | 17 | 5.3 | 7.0 | 20 | 20 |
| 4 | 1 | 11.0 | 5.0 | 5 | | | 0 | 23 | 8 | 4.0 | 8.0 | 35 | 3.6 | 6.0 | 30 | 35 |
| 5 | 1 | 8.5 | 3.5 | 7 | | | 0 | 29 | 6 | 5.0 | 5.0 | 25 | 5.0 | 6.5 | 30 | 30 |
| 6 | 1 | 50+ | 8.0 | 1 | 85 | 45 | 65 | 2 | 2 | 11.8 | 8.5 | 4 | 10.2 | 8.5 | 5 | 5 |
| 7 | 1 | 11.7 | 8.5 | 4 | | | 0 | 5 | 3 | 8.0 | 9.0 | 10 | 8.2 | 8.5 | 9 | 10 |
| 8 | 1 | 10.0 | 5.0 | 4 | | | 0 | 13 | 8 | 4.0 | 6.0 | 20 | 4.0 | 4.0 | 14 | 20 |
| 9 | 1 | 12.2 | 8.5 | 6 | T | T | 0 | 18 | 5 | 6.0 | 4.5 | 13 | 5.6 | 5.0 | 16 | 16 |
| 10 | 1 | 13.0 | 5.5 | 4 | | | 0 | 26 | 8 | 4.8 | 5.5 | 25 | 4.3 | 5.0 | 25 | 25 |
| 11 | 1 | 14.2 | 3.0 | 2 | | | 0 | 34 | 8 | 4.1 | 5.0 | 30 | 4.5 | 5.0 | 30 | 30 |
| 12 | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | |

wind velocity was 6.5 miles per hour (Col. 12). Because there was rain between 2:00 p.m. on the 2nd and 2:00 p.m. on the 3rd, the former Build-up Index must now be reduced. The rain of 19 hundredths reduces the old Build-up Index of 29 to 10, but adding a build-up factor of 5 (Col. 10) makes the new Build-up Index 15 (Col. 9). The same procedure can then be followed for the remainder of the sample period.

## INSPECTION AND TRAINING

We have observed that some agencies have left the establishment and operation of danger stations pretty much to subunit managers. This may work very well when managers have a genuine interest in danger measurement and are willing to spend some time in studying material published on the subject. But sometimes interest is lukewarm and danger measurement receives less attention than it should in view of its immediate and potential value.

The fire control agencies deriving the greatest benefit from application of danger measurement have found it desirable to place one member of the staff in charge of the system. His job has involved the personal inspection of proposed station sites, the training of district managers and observers, review of station records, and the setting up of a regular schedule of inspections.

We consider formal inspections twice a year prior to fire seasons to be a minimum. Each should require a formal report. The form on a following page has been field tested and found to be very useful. If used as a tickler list, few essential points are likely to be missed by the inspector. The form requires a minimum of preparation and provides a convenient way of recording, both for the inspector and inspectee, errors that need to be corrected or items that need follow-up. The system of scoring, as shown on the form, introduces an element of competition among observers that has been found to work very well. Most observers like to do a good job when they know what and how things are to be done. A continuing poor box score indicates the need for more training or the replacement of observers; official recognition of high scores stimulates continuation of good work and is an excellent morale builder. Where the system has been tried, an almost immediate improvement in the quality of records has been noticeable.

The need for training at all levels in fire control agencies is so generally recognized that there is no purpose in elaborating on the subject. However, one observation may be in order--poor danger station operation is more likely to be the fault of the supervisor than the observer.

## FIRE DANGER STATION INSPECTION REPORT

State or
Forest ________________ District ________________ Station ________________

Date ________________ 19___ Observer ________________ Inspector ________________

Type of Station: Open _____ Woods _____ INSPECTION RATING ________

Instructions: Opposite each condition listed below enter "1" if condition is correct, or "0" if incorrect. Compute Inspection Rating by subtracting the number of "0" conditions listed from 100. An Inspection Rating of 95 is considered standard. Ratings less than 95 point out the need for closer supervision and additional training. List all incorrect items by number under remarks on the other side of this sheet. For each item listed add an appropriate brief explanation covering repairs or adjustments made, or training given during the inspection, and indicate follow-up as needed.

---

### Rain Measurement

1. Gage location satisfactory...... ____
2. Gage firmly mounted............. ____
3. Outer can does not leak......... ____
4. Inner tube does not leak........ ____
5. Tube removed during freeze...... ____
6. Funnel top undamaged............ ____
7. Funnel top level................ ____
8. Measuring stick intact.......... ____
9. Measuring stick legible......... ____
10. Rain measured correctly......... ____

### Wind Measurement

11. Anem. location satisfactory..... ____
12. Anem. cups correct height....... ____
13. Anem. firmly mounted on mast.... ____
14. Anem. mast firm in ground....... ____
15. Anemometer plumb................ ____
16. Anem. cups not loose............ ____
17. Anem. cups not damaged.......... ____
18. Anem. cups rotate freely........ ____
19. Anem. bearings not gummed....... ____
20. Anem. bearings oiled monthly.... ____
21. Anem. casing does not leak...... ____
22. Anem. contacts adjusted......... ____
23. Wiring not loose or broken...... ____
24. Buzzer in order................. ____
25. Switch in order................. ____
26. Battery condition satisfactory.. ____
27. Battery supply adequate......... ____
28. Wind correction table used...... ____
29. Timed by second-hand of watch... ____
30. Timing procedure correct........ ____

### Fuel Moisture Measurement

31. Shelter construction adequate.... ____
32. Shelter firmly supported......... ____
33. Shelter door does not bind....... ____
34. Scale correctly mounted.......... ____
35. Scale pivot does not bind........ ____
36. Pivot block tapped before reading ____
37. Scale read accurately............ ____
38. Scale pointer swings freely...... ____
39. Scale slider set correctly....... ____
40. Slider firm but not loose........ ____
41. Scale hook does not bind......... ____
42. Hook adequate to hold sticks..... ____
43. Scale balanced at 100 grams...... ____
44. Balance correct within .1%....... ____
45. Weathering card dates correct.... ____
46. Stick location satisfactory...... ____
47. Stick shading satisfactory....... ____
48. Sticks protected (if needed)..... ____
49. Stick support adequate........... ____
50. Sticks held on support........... ____
51. Sticks proper side up............ ____
52. Correct height above litter...... ____
53. Adequate litter under sticks..... ____
54. Sticks swing free of shelter..... ____
55. Sticks clean and intact.......... ____

### Fire Danger Daily Record

56. Fire danger record legible....... ____
57. Vegetation stage correct......... ____
58. Rain recorded correctly.......... ____
59. Wind recorded correctly.......... ____
60. Fuel moisture recorded correctly. ____

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## ON DANGER MEASUREMENTS IN GENERAL

The preceding discussion of danger measurement and meters might cause some to suppose that a good system of danger measurement is the answer to most fire problems. This, decidedly, is not the impression that the writer wants to convey. At best, meters can only be a guide to judgment. But, where they have been fairly tested, their value has been so thoroughly demonstrated that doubts no longer remain.

Progress in danger measurement sometimes passes through a series of fairly definite periods. First comes a period of half-hearted compliance with orders to establish stations and to take measurements. Recommended standards are not too carefully observed and the general attitude is one of indifference. However, there always are some individuals, who out of curiosity, are sufficiently interested to back their judgment of burning conditions against those indicated by the meter. This leads to more thorough study and observation. During this period of suspended judgment comes a closer adherence to standards and therefore better records, together with a growing appreciation of the possibility of applying danger measurements in a number of ways. This is followed by better inspection and training and a general tightening-up of the network. As reliable records accumulate, it then becomes possible to apply danger measurements as a guide to woods closure, in organizational planning, as a measure of the effectiveness of prevention efforts, in the rating of one season against another, and in comparing the general effectiveness of fire control among administrative units. Finally, comes a more critical examination of the entire fire control organization and the development of better plans to cope with the fire situation.

Forest fire danger meters developed by the Southeastern Station basically are flammability meters. That is, they measure on a numerical scale the relative ease with which fires will start and spread. This being so, there is a good correlation between fire occurrence and burning index, when risk is held constant.

Through use, the Build-up Index and the Burning Index have also been found to bear a relationship to rate of spread, resistance to control, and fire severity, although at present only in broadly measureable terms. A high Burning Index is usually not reached unless there is considerable wind and, therefore, a faster than usual rate of spread. Control and mop-up become progressively more difficult in the mountains as the Build-up Index increases. Fire severity increases as the Build-up and Burning Indexes increase.

However, there are other factors that influence the above-mentioned fire phenomena and which are not included in the meters. These, among others, are topography, fuel types, upper air conditions, and severe droughts. Much more research will be necessary before these variables can be included in meters or tables supplemental to our present flammability meters.

## PARTIAL LIST OF SUPPLIERS OF FIRE-WEATHER EQUIPMENT

The following list is prepared for those interested in operating fire danger stations. The inclusion of a manufacturer's name implies no endorsement, although the specified items are believed to meet general standards set for fire danger measuring equipment. The price range indicated in parentheses is approximate and is based on recent quotations from manufacturers or suppliers.

### Fuel Moisture Scales ($32.00)

A. E. Chisholm
8532 S. E. 17th Avenue
Portland 2, Oregon

### Anemometers - Airways Type, 1/60 m.c. ($17.00-$33.00)

A. E. Chisholm
8532 S. E. 17th Avenue
Portland 2, Oregon

M. C. Stewart
Ashburnham, Mass.

Western Fire Equipment Co.
69 Main Street
San Francisco 5, Cal.

### Rain Gages - Weather Bureau Type ($23.00-$43.00)

Friez Instrument Division
Bendix Aviation Corporation
1400 Taylor Avenue near Loch Raven Blvd.
Towson, Baltimore 4, Maryland

Gichner, Inc.
1900 Kendall Street, N. E.
Washington 2, D. C.

Precision Thermometer & Instrument Co.
1434 Brandywine Street
Philadelphia 30, Pennsylvania

Science Associates
401 No. Broad Street
Philadelphia, Pennsylvania

Rain Gages - Forest Service Type ($6.25-$9.00)

F. A. Anderson Manufacturing Co.
214 N. W. Flanders Street
Portland 9, Oregon

Western Fire Equipment Company
69 Main Street
San Francisco 5, California

Rain Measuring Sticks - Weather Bureau Type ($0.50-$0.70)

Leupold & Stevens Instruments, Inc.
P. O. Box 5082
Portland 13, Oregon

Western Fire Equipment Company
69 Main Street
San Francisco 5, California

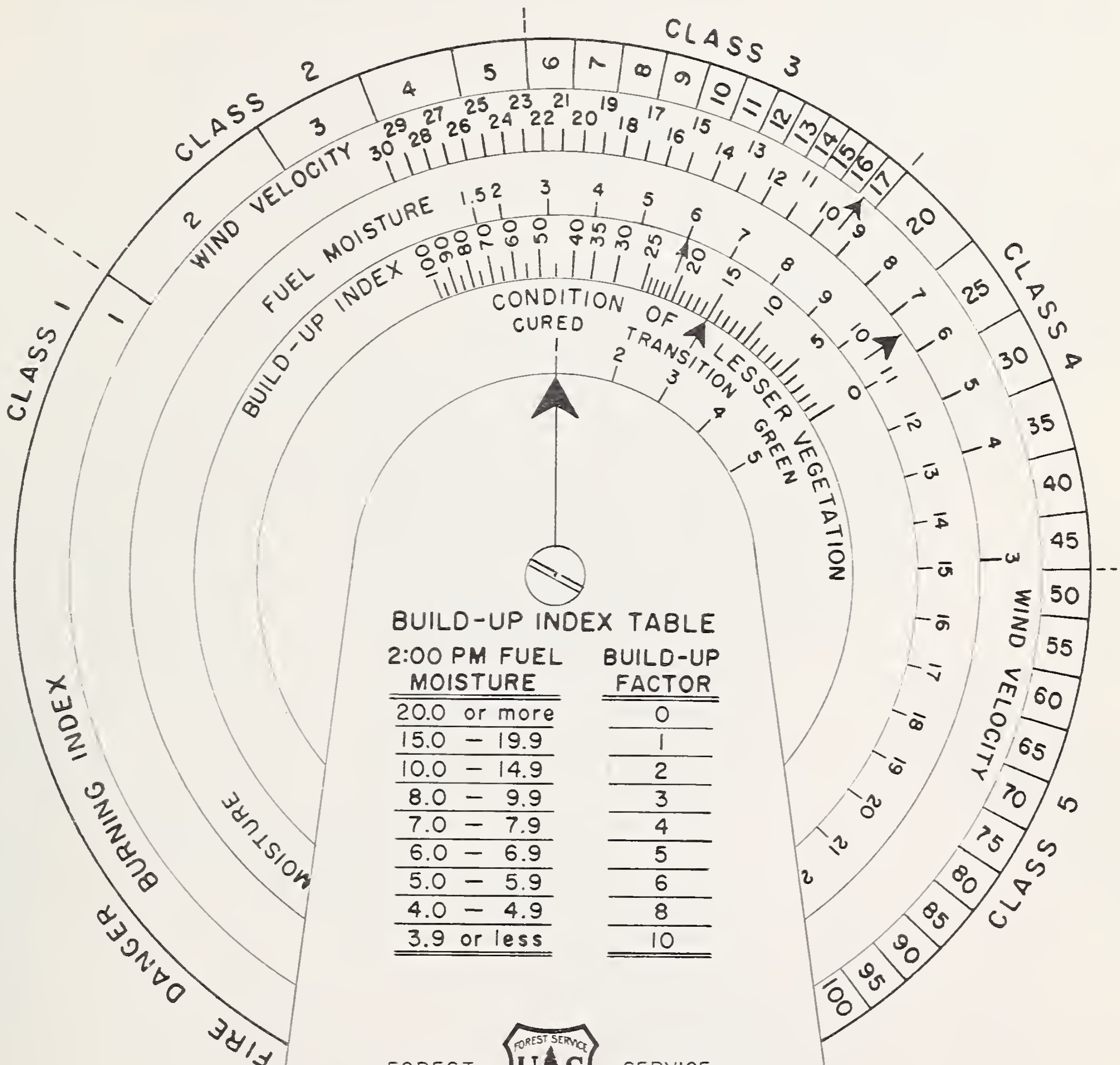
Rain Measuring Sticks - Forest Service Type ($0.15-$0.40)

F. A. Anderson Manufacturing Co.
214 N. W. Flanders Street
Portland 9, Oregon

Western Fire Equipment Company
69 Main Street
San Francisco 5, California

Agriculture-Asheville

# FOREST FIRE DANGER METER TYPE 8-100-O




## BUILD-UP INDEX TABLE

| 2:00 PM FUEL MOISTURE | BUILD-UP FACTOR |
|---|---|
| 20.0 or more | 0 |
| 15.0 — 19.9 | 1 |
| 10.0 — 14.9 | 2 |
| 8.0 — 9.9 | 3 |
| 7.0 — 7.9 | 4 |
| 6.0 — 6.9 | 5 |
| 5.0 — 5.9 | 6 |
| 4.0 — 4.9 | 8 |
| 3.9 or less | 10 |

FOREST SERVICE

U. S. Department of Agriculture

Southeastern Forest Experiment Station
Asheville, North Carolina

Agriculture--Ashevil?

October 1954